

Frame Fungi on Insulated Windows

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Insulated windows (fixed triple glass window elements), became common in Finland during and after the energy crisis. Moisture tends to condense along the edges causing mold growth on the frames. Nine houses with insulated glass windows and eight with other types of window were studied. Fungus samples were taken from the window edges and from the inside air and cultivated on malt extract agar. In five of the houses with insulated windows there was visible mold growth on the window edges. The predominant fungus was *Aureobasidium pullulans*. With other types of windows there was only one case of visible mold. The concentrations of fungi were about the same in the air of houses with both types of windows. *Aureobasidium* was rare in the air samples. Thus, window frame molds seem to contribute very little to airborne fungus concentrations. *In situ* trials were done to control the mold growth with disinfectants. Repeated spraying with aldehydes or quaternary ammonium chlorides in alcohols proved to be successful.

Key words: allergy; *Aureobasidium pullulans*; fungi; windows.

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Mold contamination of indoor air has gained increasing attention as a possible source of allergy. In many cases faulty construction or unsuitable materials have created favourable conditions for mold growth (8, 12, 14, 18). This paper presents another example.

Insulated windows (fixed triple-glass window elements) came into use in Finland around 1964 and were at their height at the beginning of the 1970's, since then there has been a gradual decline. In 1982 their use was partly prohibited by the National Housing Board. The reason was largely that originally airtight window elements started to leak and moisture entered between the glasses. Another problem was condensation water around the edges of the window during cold weather. Cold was conducted through the metal beading (Fig. 1). This condensation moisture causes mold growth. The purpose of this study was to throw light on the frequency of mold growth on the frames of insulated windows and its effect on the mold concentration of the indoor air. Also, the control of mold growth with disinfectants was tried.

MATERIAL AND METHODS

This study was done during February and March in 1984 in Jyväskylä (Central Finland) and its surroundings. Nine houses with insulated windows were studied. For comparison eight houses with removable glass windows were also studied (Table 1). Each house was visited once.

The houses were not selected at random, but volunteers were asked for through the local association of allergy patients and from among the staff of the University of Jyväskylä.

Window frame samples (usually three) were taken onto 9-cm agar plates. If the frame was moist, the sample was taken by an inoculating loop, if dry, by a stab wire dipped into agar and then drawn along the frame edge. In some cases a direct transparent tape imprint was also taken for microscopic examination (11). The tape was embedded in Aquamount® under a cover glass.

Air samples were taken by BIAP slit sampler (Mikrobiologiska och Biotekniska Testprodukter AB, Malmö, Sweden) (9) on a 14-cm agar

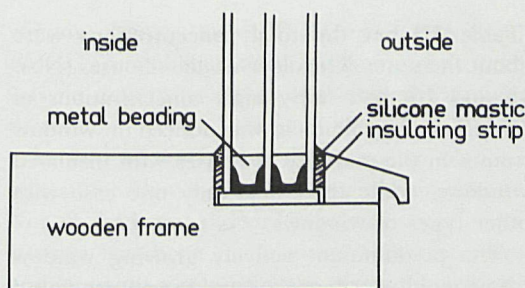


Fig. 1. The structure of insulated glass windows. In all cases the frames had been brushed with a liquid containing pentachlorophenol against fungi and then coated with lacquer.

plate. Sampling time was 10 min, which corresponds to an air sample of 0.28 m³. In a comparative study slitsamplers were found to be the best means of sampling airborne molds (2). The sampler was placed on a table in the living room, and one to three samples taken from each house.

Testing the disinfecting media. Several of the common disinfectants were tested in house No. 4 (Table 2). As the windows seemed identical, each chemical was tested on one window frame. Sterile paper towels were dipped into the disinfecting liquid, the window frame was then cleaned with a back and forth movement and the towel discarded. This was repeated three times. The frame was sprayed with Neomisept, Antifect, and Tamsept, and after 10 min excess liquid was wiped off with a dry towel. This treatment was repeated on three successive days.

Mold samples were taken with a stab wire dipped into the agar and then drawn about 20 cm along the frame edge. The agar surface was then touched 10 successive times with the wire at different points. The resulting colonies were checked after 5 days.

Culturing. The fungi were grown in room temperature on malt extract agar, which is

Table 1
Some characteristics of the houses studied

Home No.	Allergy patients	Type of windows	Type of building			Concrete or brick	Frame of building				Notes
			Detached house	Terraced house	Wood		Mechanical ventilation	Finished in year	Repaired in year	Moisture on windows	
1		A		+	+		-	-78	-	1	
2	+	A		+		+	+d	-80	-	3	a
3	+	A	+		+		-	-77	-	1	
4		A		+		+	-	-78	-	2	
5		A		+		+	-	-64	-82	0	
6	+	A	+		+		-	-74	-	3	b
7	+	A		+	+		-	-77	-	0	
8	+	A		+	+		+	-78	-	0	
9		A		+		+	+	-76	-	0	c
10		B	+		+		-	-42	-80	0	
11		B	+			+	-	-72	-	1	
12	+	B		+	+		-	-83	-	0	
13	+	B		+	+		+	-75	-	0	
14	+	C	+		+		-	-57	-	1	
15	+	D	+		+		-	-75	-	0	
16	+	D	+		+		-	-46	-83	0	
17	+	D		+	+	+	+d	-83	-	2	

Window types: A = insulation element of 3 glasses, B = insulation element of 2 glasses and a removable outer pane, C = 2 removable panes, D = 3 removable panes. Window condensation was estimated on a subjective scale: 0 = none, 1 = slight, 2 = moderate, 3 = extensive. In all cases an exhaust fan was used for mechanical ventilation.

Notes: (a) Swimming pool in apartment caused extensive window condensation, abundant mold growth and window-frame rot, (b) ceiling heaters, (c) heating by warm air circulation. There had been a bad moisture problem until the mechanical ventilation was used constantly, (d) used only periodically.

known to be a good general purpose medium for fungi (3, 19). To prevent bacterial growth and to limit the size of the mold colonies, 5 g malic acid was added to 1 l of agar (9). Mold fungi were usually identified by genus. The fungus samples that could not be immediately identified were subcultured for later study.

RESULTS

More genera of fungi were isolated from the air of houses with insulated windows (Table 3) than from those with other types of windows

(Table 4), but the total concentrations were about the same. The older wooden houses (Nos. 14 and 16) had fairly high concentrations of *Penicillium*. Visible mold was noticed on window frames in the majority of houses with insulated windows, while there was only one case with other types of windows.

The predominant actively growing window frame mold was *Aureobasidium*. It was also found on the transparent tape imprints (Fig. 2). Oddly enough, *Aureobasidium* was not found in the air of these houses, but was present in some of the others. Other fungi isolated from the

Table 2
Chemical products used in disinfectant trials

Commercial name	Manufacturer	Effective chemicals	Dilution recommended by the manufacturer
Hytox® 21	Turun Saippua Turku, Finland	Trialkylbenzylammoniumchloride 5 % Synthetic tensides 11 %	1:100
Ipasept®	Farmos Turku, Finland	Alkyldimethylbenzylammoniumchloride 1.4 % Alkyldimethylethylbenzylammoniumchloride 1.4 % Polyhexamethylenebiguanidchloride 2.3 % Synthetic tensides 5 %	1:100
Sanisept®	Farmos Turku, Finland	Alkylbenzyltrimethylammoniumchloride 2.5 % Polyhexamethylenebiguanidchloride 0.6 %	1:100
Desko®-pinta	Farmos Turku, Finland	p-Chlor-m-cresol 8 % o-Benzyl-p-chlorphenol 4 % o-Phenyl phenol 2 % Ethanol 20 % Synthetic tensides 9 %	1:50
Finosept® M	Farmos Turku, Finland	o-Benzyl-p-chlorphenol 5 % p-Chlor-m-cresol 14 % Tert. amylphenol 1 % Synthetic tensides 7 %	1:100
Sterilan	Medica Helsinki, Finland	Alkylbenzyltrimethylammoniumchloride 10 %	1:1000
Neoamisept®	Farmos Turku, Finland	Alkyldimethylbenzylammoniumchloride 0.05 % Alkyldimethylethylbenzylammoniumchloride 0.05 % Polyhexamethylenebiguanidchloride 0.1 % Isopropanol 60 %	No dilution
Antifect® Liquid	Schülke & Mayr Norderstedt, W. Germany	Glyoxal 0.1 % Ethanol 25 % n-Propanol 35 %	No dilution
Tamsept®-3	Tamro Helsinki, Finland	Glyoxal 10 % Glutaraldehyde 10 %	No dilution

window frames were *Trichoderma*, *Penicillium*, *Phoma*, *Sporobolomyces* and *Cryptococcus*, but there was no definite evidence of their active growth there.

In two of the houses there was an obvious reason for the bad moisture problem. House No. 2 had an indoor swimming pool. An attempt had been made to solve the moisture problem with a dehumidifier, but without much success. House No. 6 had ceiling heaters. This clearly demonstrates the necessity of having radiators under the windows. In the other houses it seems that good ventilation is an effective means of removing the moisture problem, although there was one exception (No. 17) for unknown reasons.

None of the washing disinfectants, even in strong concentrations, was effective in controlling the mold growth (Table 5). The best results were obtained after spraying with aldehydes or quaternary ammonium chlorides in alcohol. A

quaternary ammonium chloride in water (Sterilan®) killed the mold after prolonged treatment.

DISCUSSION

The composition and abundance of the airborne fungal flora found in the houses in this study were similar to those commonly found in houses in northern temperate regions (1, 4, 7, 10, 16, 17, 18), with the exception of *Alternaria*. In the air of several houses a puzzling slow-growing pigmented hyphomycete was found. It is named as *Scytalidium*, but so far no mycologist has been able to identify it. *Penicillium* and *Aspergillus* are common in both indoor (1, 6, 10, 16, 17) and outdoor (13, 16) air throughout the year, although these genera are more prevalent indoors than outdoors all the year round (1, 16, 17, 18), which indicates important interior sources of these fungi. The occurrence of

Table 3

Fungi found in homes with insulated glass windows. The amount of visible mold was estimated on a scale: 1 = slight, 2 = moderate, 3 = abundant. The numbers are amounts of colony forming units/m² air. Concentrations of less than 30/m³ are shown by plus (+) signs

House number	1	2	3	4	5	6	7	8	9
<i>Window frames</i>									
Visible mold	1	3	1	2 ¹	0	2	0	1 ²	1 ²
<i>Aureobasidium</i>	+	+	+	+		+			
<i>Penicillium</i>		+		+				+	+
<i>Sporobolomyces</i>		+		+					+
<i>Phoma</i>				+					
Unidentified yeast		+							
<i>Air</i>									
<i>Penicillium</i>	+	550	+			50	+	+	+
<i>Scytalidium?</i>	65	45			+		+		+
<i>Cladosporium</i>				+	+		+	+	
<i>Rhizopus</i>		+	+					+	
<i>Phoma</i>						+		+	
<i>Sphaeropsidales</i> (unident.)		+						+	
<i>Aspergillus niger</i>		30							
<i>Aspergillus</i> sp.					+				
<i>Sporobolomyces</i>				+					
Unidentified yeast							+		
<i>Botrytis</i>								+	
<i>Chrysosporium</i>								+	
Sterile mycelia				+		+	+	+	
Total conc. in air	70	630	+	+	+	60	+	+	+

¹ Abundant *Aureobasidium* on tape print (Fig. 2).

² Mold on tape print, only dirt.

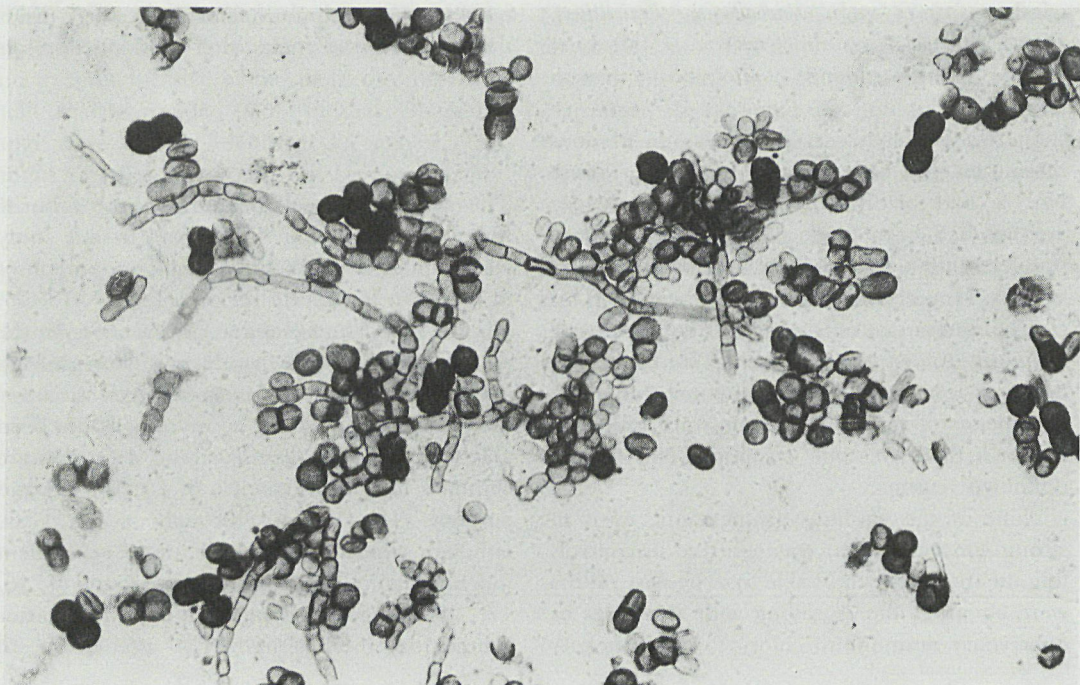


Fig. 2. Sticky tape imprint from a window frame from house No. 4. Mostly dark thick-walled hyphae of *Aureobasidium pullulans* can be seen. Hyphal fragments act like chlamydospores or arthroconidia.

Aureobasidium has been found to be slightly more common outdoors than indoors (1, 4, 15, 16). During winter the fungus prevalence is clearly higher indoors than outdoors (17).

Most other fungi have a peak occurrence period during summer and autumn both indoors and outdoors (1, 6, 13, 16, 17). During frost-free periods the airborne fungus prevalence is clearly higher outdoors than indoors (1, 16, 17). These findings indicate mainly outdoor sources for these fungi.

The fungus prevalence is usually about the same in the different rooms of a residence (6), which means that measurements in the living-room are usually enough to assess indoor mold prevalence. Moist basements produced more airborne fungus spores (10, 15).

Of the fungi found on window frames *Aureobasidium* is known to damage painted surfaces (8) and wall papers (14) but primarily attacks the leaves of plants (5). *Trichoderma* is known to attack damp timber and thus can grow actively on window frames. Some species

of *Penicillium* and *Phoma* are cellulolytic (5) and thus may grow actively. *Penicillium* was also isolated from windows with no visible mold; it is probable that the colonies grew from airborne conidia that had settled on the frames. The role of yeasts (e.g. *Sporobolomyces* and *Cryptococcus*) in window frame flora is obscure. *Cladosporium* has been reported to grow abundantly on moist window frames (8), but this was not found in the present study. Settled house dust is a probable source of nourishment for all of these fungi.

It is obvious that window frame molds contribute very little to the indoor-air mold-spore concentration, despite the updraught from radiators below the windows. *Aureobasidium* has slimy masses of conidia, which are not easily airborne. The situation may be different when the window frames become dry, e.g. during spring.

Aureobasidium was found more often in house dust than in house air (7), which also indicates that it is not airborne easily. It is possible that

the propagules of *Aureobasidium* in the air are not always viable and therefore an air sample for direct microscopical counting should also have been taken (12): *Aureobasidium* is capable of causing allergy (8, 14, 20).

Window frame mold is difficult to suppress. Because of the persistence of suitable growth conditions, the treatment must be repeated 1-2 times a week. Disinfectants are not usually added to normal household chemicals but are intended for hospitals, institutes, etc. The best method is normal cleaning and then spraying with quaternary ammonium chlorides or aldehydes

in alcohol. If alcohols are harmful to paints or other materials, treatment with similar chemicals in water are recommended.

These preliminary findings require further study as the material is limited. Further research should also be made of other possible sources of allergenic fungi in homes. It is also important to study simultaneously several characteristics of buildings and domestic housing, especially the moisture and ventilation systems.

Mold growth seems to be a common problem with insulated windows. The mold gradually

Table 4

Fungi found in homes with removable glass windows. Other explanations as in Table 3

House number	10	11	12	13	14	15	16	17
<i>Window frames</i>								
Visible mould	0	0	0	0	0	0	0	1
<i>Penicillium</i>			+		+	+	+	
<i>Aureobasidium</i>		+						
<i>Cryptococcus</i>								+
<i>Air</i>								
<i>Penicillium</i>		+	60	+	4500	230	800	
<i>Cheiramyces</i>		+						+
<i>Cladosporium</i>		+		+				
<i>Aureobasidium</i>		+					+	
<i>Mucor</i>							+	
<i>Trichoderma</i>							+	
Sterile mycelia				+				+
Total conc. in air	0	40	60	+	4500	230	850	+

Table 5

Results of the *in situ* trials to suppress the growth of window frame molds.

Chemical	Tensides	Quatern. amm. chlorides	Phenols	Aldehydes	Dilution		No dilution
					1:100	1:10	
Hytox 21	+	+			2	2	-
Ipasept	+	+			2	2	-
Sanisept	+	+			2	2	-
Desko-pinta	+		+		2	2	-
Finosept	+		+		2	2	-
Sterilan		+			2	1,0*	-
Neoamisept	+				-	-	0
Antifect				+	-	-	0
Tamsept 3				+	-	-	0

* Prolonged treatment on 6 successive days.

2 = growth at all points, 1 = growth at some points, 0 = no growth, - = not tested.

decays the wooden frames and creates a possible allergy risk. The dark deposit resulting from *Aureobasidium* is also a nuisance. For these reasons the desirability of fitting this type of window in new dwelling-houses may be questionable.

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